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# Observation of a resonance with a mass near 125 GeV in the search for the Higgs boson in pp collisions at $\sqrt{s} = 7$ TeV and 8 TeV.

This is a condensed description with plots for the analysis CMS-HIG-12-020

## Abstract

Combined results are reported from searches for the standard model Higgs boson in proton-proton collisions at  $\sqrt{s} = 7$  TeV and 8 TeV in five final state modes:  $\gamma\gamma$ ,  $bb$ ,  $\tau\tau$ ,  $WW$ , and  $ZZ$ . The analysed data correspond to integrated luminosities up to  $5.1 \text{ fb}^{-1}$  at 7 TeV and  $5.3 \text{ fb}^{-1}$  at 8 TeV. The data exclude the existence of a SM Higgs boson in the ranges 110–122.5, 127–600 GeV at 95% confidence level. An excess of events above the expected SM background is observed with a local significance of  $4.9\sigma$  for a Higgs boson mass hypothesis of around 125 GeV. We interpret this to be due to the production of a previously unobserved particle with a mass of around 125 GeV. The evidence is strongest in the two final states with the best mass resolution: firstly the two-photon final state and secondly the final state with two pairs of charged leptons (electrons or muons). The excess in these final states alone, above the expected SM background, gives a local significance of  $5.0\sigma$ . An unconstrained fit to these excesses yields a mass of  $125.3 \pm 0.4$  (stat)  $\pm 0.5$  (syst) GeV. Within the statistical uncertainties, the results obtained in the different search channels are consistent with the expectations for a SM Higgs boson. More data are needed to test whether this new state has all the properties of the SM Higgs boson or whether some do not match, implying new physics beyond the standard model.

## Sensitivities

Plot	Caption
	<b>The median expected 95% CL upper limits on the cross section ratio <math>\sigma/\sigma_{\text{SM}}</math></b> in the absence of a Higgs boson as a function of the SM Higgs boson mass in the range 110–600 GeV (left) and 110–145 GeV (right), for the five Higgs boson decay channels. Here $\sigma_{\text{SM}}$ denotes the cross section predicted for the SM Higgs boson. A channel showing values below unity (dotted red line) would be expected to be able to exclude a Higgs boson of that mass at 95% CL. The jagged structure in the limits for some channels results from the different event selection criteria employed in those channels for different Higgs boson mass sub-ranges.
	<b>The median expected <math>p</math>-value for observing an excess</b> at mass $m_{\text{H}}$ in assumption that the SM Higgs boson with this mass exists, as a function of the SM Higgs boson mass in the range 110–600 GeV (left) and 110–145 GeV (right). Expectations for subcombinations in five Higgs boson decay channels and the overall combination are shown.

## Additional plots

Plot	Caption
	<b>The median expected <math>p</math>-value for observing an excess</b> at mass $m_{\text{H}}$ in assumption that the SM Higgs boson with this mass exists, as a function of the SM Higgs boson mass in the range 110–600 GeV (left) and 110–145 GeV (right). Expectations for the two sub-combinations of low mass resolution and high mass resolution channels are shown.
	<b>The median expected <math>p</math>-value for observing an excess</b> at mass $m_{\text{H}}$ in assumption that the SM Higgs boson with this mass exists, as a function of the

	SM Higgs boson mass in the range 110–600 GeV (left) and 110–145 GeV (right). Expectations for the two sub-combinations of fermionic and bosonic decay modes are shown.
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## Exclusion limits on the SM Higgs boson

Plot	Caption
	<b>The <math>CL_s</math> values for the SM Higgs boson hypothesis as a function of the Higgs boson mass.</b> The observed values are shown by the solid line. The dashed line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively. The three horizontal lines on the $CL_s$ plot show confidence levels of 90%, 95%, and 99%, defined as $(1-CL_s)$ .
	<b>The 95% CL upper limits on the cross section ratio <math>\sigma/\sigma_{SM}</math> for the SM Higgs boson hypothesis as function of the Higgs boson mass.</b> The observed values are shown by the solid line. The dashed line indicates the expected median of results for the background only hypothesis, while the green (dark) and yellow (light) bands indicate the ranges that are expected to contain 68% and 95% of all observed excursions from the median, respectively.

## Significance of the observed excess

Plot	Caption
	<b>The observed local <math>p</math>-value <math>p_0</math> for 7-TeV, 8-TeV data, and their combination</b> as a function of the SM Higgs boson mass. The dashed lines show the expected local $p$ -value $p_0(m_H)$ , should a Higgs boson with a mass $m_H$ exist.
	<b>The observed local <math>p</math>-value <math>p_0</math> for five subcombinations by decay mode and the overall combination</b> as a function of the SM Higgs boson mass. The dashed lines show the expected local $p$ -value $p_0(m_H)$ , should a Higgs boson with a mass $m_H$ exist.
	<b>The observed local <math>p</math>-value <math>p_0</math> for <math>\gamma\gamma</math>, <math>ZZ</math> and their combination</b> as a function of the SM Higgs boson mass. The dashed lines show the expected local $p$ -value $p_0(m_H)$ , should a Higgs boson with a mass $m_H$ exist.
	<b>The observed local <math>p</math>-value <math>p_0</math> for <math>\gamma\gamma</math>, <math>ZZ</math>, <math>WW</math> and their combination</b> as a function of the SM Higgs boson mass. The dashed lines show the expected local $p$ -value $p_0(m_H)$ , should a Higgs boson with a mass $m_H$ exist.
	<b>The observed local <math>p</math>-value <math>p_0</math> as a function of the SM Higgs boson mass, separately for searches with the 7 TeV and 8 TeV datasets.</b> The dashed lines show the expected local $p$ -value $p_0(m_H)$ , should a Higgs boson with a mass $m_H$ exist.

## Additional plots

Plot	Caption
	<b><math>ZZ+\gamma\gamma</math>:</b> The observed local $p$ -value $p_0$ for 7-TeV, 8-TeV data, and their combination as a function of the SM Higgs boson mass, in decay modes with good mass resolution. The dashed lines show the expected local $p$ -value $p_0(m_H)$ , should a Higgs boson with a mass $m_H$ exist.

	<b>WW+bb+ : The observed local <math>p</math>-value <math>p_0</math> for 7-TeV, 8-TeV data, and their combination</b> as a function of the SM Higgs boson mass, in decay modes with poor mass resolution. The dashed lines show the expected local $p$ -value $p_0(m_H)$ , should a Higgs boson with a mass $m_H$ exist.
	<b>The observed local <math>p</math>-value <math>p_0</math> for the sub-combinations of high mass resolution channels, low mass resolution ones, and the overall combination</b> as a function of the SM Higgs boson mass. The dashed lines show the expected local $p$ -value $p_0(m_H)$ , should a Higgs boson with a mass $m_H$ exist.
	<b>The observed local <math>p</math>-value <math>p_0</math> for the sub-combinations of bosonic and fermionic decay modes and the overall combination</b> as a function of the SM Higgs boson mass. The dashed lines show the expected local $p$ -value $p_0(m_H)$ , should a Higgs boson with a mass $m_H$ exist.

## Mass of the observed state

Plot	Caption
	(Left) <b>2D 68% CL contours for a hypothesized Higgs boson mass <math>m_H</math> and signal strength <math>\mu / \mu_{SM}</math></b> for the untagged $\gamma\gamma$ , with VBF-like dijet, and 4l, and their combination. In this combination, the relative signal strengths for the three final states are constrained by the expectations for the SM Higgs boson. (Right) <b>1D test statistics <math>q(m_H)</math> scan vs hypothesized Higgs boson mass <math>m_H</math></b> for the untagged $\gamma\gamma$ , with VBF-like dijet, and 4l final states separately and for their combination. In this combination, signal strengths for the untagged $\gamma\gamma$ , gamma; with VBF-like dijet, and 4l final states are not constrained by the expectations for the SM Higgs boson.

## Additional plots

Plot	Caption
	<b>1D test statistics <math>q(m_H)</math> scan vs hypothesized Higgs boson mass <math>m_H</math> for the combination of the high resolution channels.</b> The dashed line shows the value of $q(m_H)$ if all parameters except $m_H$ are kept fixed at the values corresponding to the global best fit for $m_H$ . In this combination, signal strengths for the untagged $\gamma\gamma$ , gamma; with VBF-like dijet, and 4l final states are not constrained by the expectations for the SM Higgs boson. The horizontal and vertical red lines denote the 68% and 95% CL intervals.
	<b>2D test statistics <math>-2 \ln Q</math> vs hypothesized Higgs boson mass <math>m_H</math> and signal strength <math>\mu / \mu_{SM}</math> for the combination of the high resolution channels.</b> The cross indicates the best-fit values. The solid and dashed contours show the 68% and 95% CL ranges, respectively. In this combination, the relative signal strengths for the various final states are constrained by the expectations for the SM Higgs boson.
	<b>2D test statistics <math>-2 \ln Q</math> vs hypothesized Higgs boson mass <math>m_H</math> and signal strength <math>\mu / \mu_{SM}</math> for the diphoton final state.</b> The cross indicates the best-fit values. The solid and dashed contours show the 68% and 95% CL ranges, respectively. In this combination, the relative signal strengths for the various production modes are constrained by the expectations for the SM Higgs boson.
	<b>2D test statistics <math>-2 \ln Q</math> vs hypothesized Higgs boson mass <math>m_H</math> and signal strength <math>\mu / \mu_{SM}</math> for the four-lepton final state.</b> The cross indicates the best-fit values. The solid and dashed contours show the 68% and 95% CL ranges, respectively.

## Compatibility of the observed state with the SM Higgs boson hypothesis

Plot	Caption
	The observed best-fit signal strength $\mu = \sigma / \sigma_{SM}$ as a function of the SM Higgs boson mass in the range 110–145 GeV. The bands correspond to the $\pm 1$ uncertainties on the $\mu$ values.
	The observed best-fit signal strength $\mu = \sigma / \sigma_{SM}$ as a function of the SM Higgs boson mass for the 7 TeV and 8 TeV dataset separately, in the range 110–145 GeV. The bands correspond to the $\pm 1$ uncertainties on the $\mu$ values.
	The observed best-fit signal strength $\mu = \sigma / \sigma_{SM}$ as a function of the SM Higgs boson mass for the 7 TeV and 8 TeV dataset separately, in the range 110–145 GeV. The bands correspond to the $\pm 1$ uncertainties on the $\mu$ values.
	Values of $\mu = \sigma / \sigma_{SM}$ for the combination (solid vertical line) and for contributing channels (points). The vertical band shows the overall $\mu$ value $0.80 \pm 0.22$ . The horizontal bars indicate the $\pm 1$ uncertainties on the $\mu$ values for individual channels; they include both statistical and systematic uncertainties.
	Values of $\mu = \sigma / \sigma_{SM}$ for the combination (solid vertical line) and for sub-combinations grouped by decay mode (points). The vertical band shows the overall $\mu$ value $0.80 \pm 0.22$ . The horizontal bars indicate the $\pm 1$ uncertainties on the $\mu$ values for individual channels; they include both statistical and systematic uncertainties.
	Values of $\mu = \sigma / \sigma_{SM}$ for the combination (solid vertical line) and for sub-combinations grouped by a signature enhancing specific production mechanisms (points). The vertical band shows the overall $\mu$ value $0.80 \pm 0.22$ . The horizontal bars indicate the $\pm 1$ uncertainties on the $\mu$ values for individual channels; they include both statistical and systematic uncertainties.
	Values of $\mu = \sigma / \sigma_{SM}$ for the combination and for contributing channels, for the 7 TeV and 8 TeV datasets separately. The horizontal bars indicate the $\pm 1$ uncertainties on the $\mu$ values; they include both statistical and systematic uncertainties.
	The 2D-scan of the test statistic $-2 \ln Q$ vs $(c_V, c_F)$ parameters. The cross indicates the best-fit values. The solid and dashed contours show the 68% and 95% CL ranges, respectively. The diamond indicates the SM value $(c_V, c_F) = (1,1)$ . In this scan, the Higgs boson mass is assumed to be 125 GeV.

### Additional plots

Plot	Caption
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|| 1D test statistics  $q(R_{W/Z})$  scan vs the event rate modifier  $R_{W/Z}$ , profiling all other nuisances and the signal strength modifier  $\mu_{ZZ}$ . The search channels included are the H WW channel with zero jets and one jet in the final state, and the inclusive H ZZ search. The horizontal and vertical red lines denote the 68% and 95% CL intervals. In this scan, the Higgs boson mass is assumed to be 125 GeV. |

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